

## Lead-Tin-Arsenic Wiping Solder\*

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SOME fourteen or more wiped joints occur in every mile of lead-sheathed telephone cable, and in making these joints from one to two million pounds of solder are used per year. To join cables a lead sleeve of sufficient diameter to accommodate the bundle of spliced wires is slid in place at the junction, the ends of the sleeve are beaten to conform to the circumference of the cable, and an air-tight and mechanically strong joint formed at each end of the sleeve by molding a solidifying mass of solder into the desired shape. This last step is called the wiping operation.

The making of a successful wiped joint depends upon a satisfactory composition in the solder and considerable skill on the part of the splicer. The two factors are inter-related in that the more dextrous operators can produce satisfactory joints with solder compositions which could not be shaped by the average operator. The most satisfactory composition for a wiping solder from practical tests has been found to be about 38 per cent tin, 62 per cent lead. A solder containing 40 per cent tin also possesses satisfactory handling qualities and is used to some extent. If the tin content is much above 40 per cent the workable temperature range in which the solder is plastic becomes too limited for practical handling. The plastic range can be increased by increasing the lead content above 62 per cent but then it is found that the joint becomes coarse-grained and porous. The highest practicable lead content is of course advantageous from an economic standpoint.

The impurities allowable in a wiping solder are also closely controlled since in general small percentages of most impurities have been found to have a harmful effect upon the handling character of the solder or the properties of the joints. One exception, which has hitherto not been recognized, is arsenic whose beneficial effects in small quantities are discussed in this paper.

An engineer would prefer to interpret the handling of a wiping solder in terms of basic properties which can be measured in the laboratory. Such attempts<sup>1</sup> have been made but with only limited success since

\* *Metals and Alloys*, Vol. 11, pp. 75-76, March 1940.

<sup>1</sup> "Some Physical Properties of Wiping Solders," D. A. McLean, R. L. Peek, Jr., and E. E. Schumacher, *Journal of Rheology*, Vol. 3, January 1932, p. 53.

not only does the wiping process itself not admit of scientific measurement but also the basic properties related to the process are difficult to determine and are of restricted practical bearing. These difficulties arise because a complex solid-liquid system is involved, and during most of the time of wiping the joint the system is far from being in an equilibrium condition.

Experience has shown, however, that a wiping solder should possess certain general characteristics which are enumerated below, although in many instances the characterization cannot be extended beyond a qualitative statement.

1. The temperature at which the solder begins solidification should be lower than the temperature of beginning melting of the cable sheath and sleeve. The temperature of beginning solidification for the 38-62 tin-lead solder is  $240^{\circ}\text{C}$ . while the lead alloy sheath begins to melt at approximately  $310^{\circ}\text{C}$ . Since with this solder no trouble is encountered with melting sheath it appears that a  $70^{\circ}$  differential is satisfactory.

2. The solidification range of the solder should be such as to provide, during cooling, an ample forming period between the time when enough primary lead has precipitated to give sufficient body to permit forming to begin until the mass is too solid to manipulate. In the 38-62 wiping solders the solidification range is approximately  $60^{\circ}\text{C}$ . while the forming range is about  $40^{\circ}\text{C}$ .

3. The tendency for the joint to drain or slip and break apart during wiping should be a minimum. These properties are associated with surface tension and plasticity. The desired condition is sometimes referred to as a "buttery" texture.

4. The solder should readily wet and alloy with the parts to be joined. This implies a freedom from non-reducible oxides in the solder and a minimum in the tendency to form reducible oxides. Suitable non-corrosive fluxes are used to clean the surfaces being joined and reduce the oxides which cannot be entirely excluded from the melted solder. To facilitate handling, the solder should not adhere to the splicers' wiping cloths.

5. The solder should be such that the strength of the joint formed should be equal to or greater than that of the parts being joined. The joint must also be gas-tight. This property is secured through a fine texture in the solder and freedom from draining of the lower melting constituents. The test for porosity of a joint is simple. A positive gas pressure of from six to nine pounds per square inch is applied inside the sleeve and soap-suds are then painted on the joint. Observation of the soap-suds will then show whether or not the joint is porous.

6. The health hazard under normal conditions of use should be negligible.

An investigation was made of modifications of the lead-tin type wiping solder to produce a solder which more fully meets the practical requirements than does the present compositions. Through the addition of 0.1 per cent of arsenic substantial improvements have been

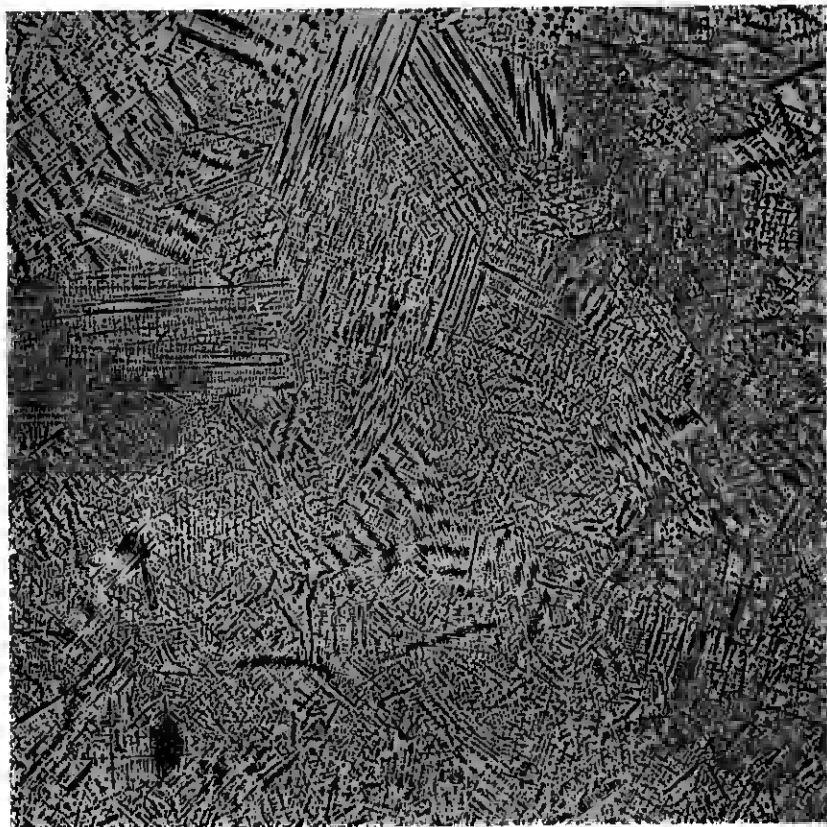


Fig. 1—Photomicrograph of a nominal 38% tin-62% lead wiping solder. The sample was slowly cooled from 300° C. Specimen etched with a mixture of 4 parts of glacial acetic acid and 1 part of 30% hydrogen peroxide.

achieved in certain of the characteristics. The nominal composition of an alloy which shows this improvement is tin—37.25 per cent, arsenic—0.1 per cent, and balance lead. The effect of arsenic manifests itself at percentages as low as 0.04 per cent. Amounts much over 0.1 per cent should be avoided because of a tendency to segregation at the higher percentages. As the tin is reduced below the recom-

mended percentage the difficulties in producing a satisfactory joint increase. There is the possibility, however, that a lower tin content can be tolerated but definite conclusions await further substantiation in subsequent investigation.

Although the percentage of arsenic in the new solder is relatively small it has two important beneficial effects. The amount of dross formed on the arsenic-bearing solder is but a fraction of that ex-

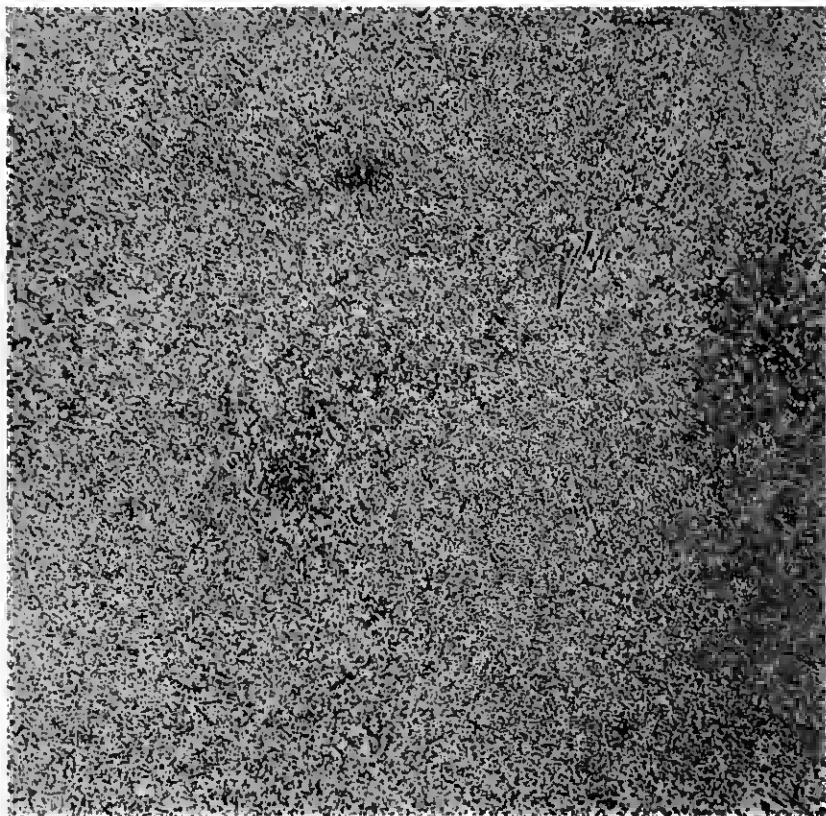


Fig. 2—Same as Fig. 1, except for an addition of 0.1% arsenic. Note the finer grain.

perienced in the ordinary lead-tin solders. The practical advantage is that less time need be spent in skimming the molten solder in the melting pot, and there is less possibility for the inclusion of dross in the finished joints. The presence of dross in the wiped joints is to be avoided because of its possible contribution to porosity.

The second beneficial effect of arsenic is related to the grain size in the solidified alloy. This is illustrated by the photomicrographs shown in Figs. 1 and 2 which compare the grain structure of a lead-tin solder

and an arsenic-modified solder which have undergone similar handling and cooling treatments. The arsenic-bearing solder exhibits a finer and more uniform texture. The finer texture is associated with improved handling characteristics and freedom from porosity in the finished joint. The texture of the solder is more buttery in the wiping process and there is less tendency for the lower freezing constituents to drain from the partially finished joints than with the lead-tin compositions. Practically, this provides for the splicer a longer forming range, although the solidification range is materially the same as for the corresponding unmodified alloy.

Although the mechanism by which arsenic reduces the size of the dendrites and refines the grain of wiping solder has not been definitely established, it seems probable that it either provides new and more numerous nuclei of crystallization around which the primary lead precipitates, or imposes barriers against the growth of the primary lead crystals or both. Arsenic forms a compound,  $\text{Sn}_3\text{As}_2$ , with tin and it is probable that this constituent is responsible for the mechanism postulated. In slowly cooled solders this compound is discernible beginning at approximately 0.1 per cent arsenic. With a greater number of precipitated crystals present a greater surface is made available to which the molten eutectic may cling, producing a readily formable mass.

Laboratory observations on the solder have been verified by field tests in the Bell System. The arsenic-bearing solder is handled in the same way as the ordinary lead-tin compositions. Joints have been wiped on large and small aerial and underground cables and in difficult situations involving large branched joints. The consensus of splicers from several different localities is that the solder possesses handling properties superior to those of the lead-tin compositions. These joints in all cases were pressure tested after wiping and found to be sound.

Regarding the possible health hazard involved in using the new solder, tests have been made to determine whether arsenic or arsenic compounds would be volatilized from this alloy under the conditions encountered in practice. These tests gave entirely negative results and showed that no additional hazards would be introduced by substituting arsenic-bearing solder for standard solder.